
फ्लाई ऐश का उपयोगीकरण — दिशा-निर्देश
(पहला पुनरीक्षण)

Utilization of Fly Ash — Guidelines
(First Revision)

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FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards after the draft finalized by the Solid Waste Management Sectional Committee, had been approved by the Chemical Division Council.

Fly ash is a finely divided residue resulting from the combustion of ground or powdered coal/combustible waste and transported by the flue gases of boilers fired by pulverized coal. It is available in large quantities in the country from a number of thermal power stations and industrial plants using pulverised coal/waste as fuel for the boilers.

At present there are hundreds of thermal power plants/waste to energy conversion plants in the country producing over 100 million tonnes of fly ash per annum. The ash content of most of the coal used in these plants is above 35 percent. Since, low ash, high grade, coal is reserved for metallurgical industries, railways, etc., the thermal power plants have to utilize high ash, low grade, coal and by-product fuel from coal washeries. It has been estimated that the average ash content of coal which will be available for thermal power plants in the coming years will further increase.

The use of fly ash as a pozzolana, a fine aggregate and for other allied purposes is well established in India. Investigations have proved the suitability of fly ash for various uses. Indigenous fly ashes for partial replacement of cement, as an admixture for concrete and as a fine aggregate for mortar and concrete have already been successfully tried out and greater attention is now being paid to fully exploit the potentialities of fly ash as construction material.

Disposal of fly ash is a problem being faced by most of the thermal power plants where it is being produced. This material, however, may be utilized in a number of ways, some of which have been mentioned above. If proper means and methods are not adopted for utilization of fly ash the problem will increase in magnitude, due to its increased production, over the next few years.

This standard was initially published in 1982 with considerable assistance taken from the literature of Central Building Research Institute (CBRI), Roorkee and Central Road Research Institute (CRRI), New Delhi. Over the course of time, uses and disposal methods of flyash has changed significantly.

During this first revision, the recent developments with regard to standardized uses and their techniques have been explored and guidelines have been provided.

The composition of technical committee responsible for formulation of this standard is given in Annex A.

Indian Standard

UTILIZATION OF FLY ASH — GUIDELINES

(First Revision)

1 SCOPE

1.1 This standard lays down guidelines for utilization of fly ash.

1.2 Fly ash may be collected from the flue gases, in thermal power plants, by mechanical collectors or electrostatic precipitators or a combination of both. It may be removed by “wet system” or “dry system”. The ‘wet system’ involves mixing the fly ash with water and sluicing it to a settling tank or dumping areas. The ‘dry system’ involves removal of the fly ash in dry form either directly by screw feeders discharging into transport vehicles from the hoppers or by means of pneumatic conveying system for further utilization or storage.

2 REFERENCES

The Indian Standards listed below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate by dated or undated the possibility of applying the most recent editions of the standards.

<i>IS No</i>	<i>Title</i>
456 : 2000	Plain and reinforced concrete — Code of practice
712 : 1984	Specification for building limes
1489 (Part 1) : 2015	Portland pozzolana cement — Specification: Part 1 Fly ash based
2042 : 2006	Insulating bricks — Specification
2541 : 1991	Preparation and use of lime concrete — Code of practice
2686 : 1977	Cinder as fine aggregates for use in lime concrete
3466 : 1988	Specification for masonry cement
3812 (Part 1) : 2013	Specification for pulverized fuel ash: Part 1 For use as Pozzolana in cement, cement mortar and concrete
3812 (Part 2) : 2013	Pulverized fuel ash: Part 2 For use as admixture in cement mortar and concrete

<i>IS No</i>	<i>Title</i>
4332 Series	Methods of test for stabilized soils
4926 : 2003	Code of practice ready-mixed concrete
5817 : 1992	Preparation and use of lime-pozzolana mixture concrete in buildings and roads — Code of practice
8229 : 1986	Specification for oil-well cement
9142 (Part 2) : 2018	Artificial lightweight aggregate for concrete specification: Part 2 Sintered fly ash coarse aggregate (first revision)
10359 : 1982	Code of practice for manufacture and use of lime-pozzolana concrete blocks for paving
10360 : 1982	Specification for lime-pozzolana concrete blocks for paving
12894 : 2002	Pulverized fuel ash-lime bricks — Specification
13757 : 1993	Burnt clay fly ash building bricks — Specification
15648 : 2006	Pulverized fuel ash for lime-pozzolana mixture applications — Specification
16720 : 2018	Pulverized fuel ash-cement bricks — Specification

3 TERMINOLOGY

For the purpose of this standard the following definitions shall apply:

3.1 Fly Ash Concrete — Portland cement concrete in which a part of the cement has been replaced by fly ash.

3.2 Ready Mixed Fly Ash Concrete — Concrete which is prepared and supplied to consumers in a plastic, unhardened, ready-for-use state.

4 UTILIZATION OF FLY ASH

4.1 Fly ash is a suitable raw material for a variety of products. It can be utilized without further processing

also, provided it meets the requirements of the standards for such uses, if available. It can be utilized for the production of:

- a) Portland pozzolana cement (using fly ash as pozzolana),
- b) Cement-fly ash concrete and ready-mixed fly ash concrete,
- c) Precast fly ash concrete building units,
- d) Sintered fly ash light weight aggregate and concrete,
- e) Lime-fly ash cellular concrete,
- f) Cement/lime/silicate bonded and clay-fly ash building bricks/blocks/tiles etc,
- g) Portland cement clinker,
- h) Oil-well cement
- j) masonry cement,
- k) Various types of concrete for road and airfield pavement construction:
 - 1) lime-fly ash concrete,
 - 2) lean cement-fly ash concrete,
 - 3) cement-fly ash concrete,
 - 4) lime-fly ash soil stabilization, and
 - 5) lime-fly ash bound macadam.

4.2 It can also be used as a suitable material for:

- a) embankment construction as a fill material,
- b) Bituminous concrete as a filler material,
- c) Low lying area as a fill material
- d) Abandoned mines as a filling material,
- e) Agriculture/waste land development, and
- f) Construction of dams.

5 PORTLAND POZZOLANA CEMENT (USING FLY ASH AS POZZOLANA)

5.1 Portland pozzolana cement (using fly ash as pozzolana) shall be manufactured either by intergrinding Portland cement clinker, fly ash and gypsum or by intimately and uniformly blending Portland cement and fly ash in accordance with IS 1489 (Part 1).

5.2 The intergrinding method does not involve any major addition to the plant and equipment already available at a cement factory. The blending process requires installation of a suitable blender or homogenizer. In India, Portland-pozzolana cement (using fly ash as pozzolana) is being produced over the past few years by the intergrinding process.

5.3 Most of the indigenous fly ash possess good pozzolanic activity and are suitable for use in the manufacture of Portland pozzolana cement (using fly ash as pozzolana). The Portland pozzolana cement (using fly ash as pozzolana) having its strength at

par with that of ordinary Portland cement at 7 days and conforming to the other requirements of IS 1489 (Part 1) can be used in place of ordinary Portland cement in construction works.

6 CEMENT-FLY ASH CONCRETE AND READY MIXED FLY ASH CONCRETE

6.1 The process of producing ready mixed fly ash concrete mainly consists of two operations as follows:

- a) Proportioning of fly ash concrete mix; and
- b) Batching and mixing of different ingredients.

6.2 The fly ash concrete mix is specially proportioned in order to attain required 28 day compressive strength optimally, equal to that of the corresponding mix of plain cement concrete. A number of methods of proportioning fly ash concrete mix are now available to achieve equal 28 day compressive strength. The quality of ready mixed fly ash concrete depends upon the quality of its ingredients, their proportions and thoroughness with which these are combined. The mixing of different ingredients may be done either at a central mixing plant or during transit in a truck mixer. IS 456 provides the practice for plain and reinforced concrete.

6.3 Ready mixed fly ash concrete has advantages such as better quality control and reduction in wastage, labour and supervision. As compared to plain cement ready mixed concrete, it is cheaper and there is a direct saving of cement up to 20 percent. IS 4926 provides the practice for ready mix concrete.

7 PRECAST FLY ASH CONCRETE BUILDING UNITS

7.1 The use of fly ash in the production of various types of precast building units such as concrete building blocks (solid or hollow), RCC transmission poles, columns, beams, hollow core slabs and door and window frames is also being explored.

7.2 It was observed that breakage of these units during handling at the time of removal from the casting yard and subsequent stacking for water curing was more. The higher breakage in the fly ash concrete units could be, obviously, due to their having lower strength at one or two days when the units were removed. Fly ash concrete with 20 percent less cement, by mass, than the corresponding plain cement concrete can be so proportioned as to attain equal one-day compressive strength. With equal one-day strength precast fly ash concrete units can be lifted and handled in the same manner as the corresponding plain cement concrete units.

7.3 Large number of precast hollow concrete building blocks, flooring and roofing units, such as cored units

channel units and cellular units produced using fly ash concrete having 20 percent less cement, by mass than the corresponding plain cement have been found to have comparable strength and other structural properties.

8 SINTERED FLY ASH LIGHTWEIGHT AGGREGATE AND CONCRETE

8.1 Fly ash contains a large proportion of minute spherical glassy particles. When heated at 1100 °C-1200 °C, these glassy spheroids soften and cohere to form a vitrified structure. The process of causing this cohesion is termed 'sintering' and the sintered agglomerates are called sintered fly ash lightweight aggregate (SFALA).

8.2 The manufacture of SFALA mainly involves the following two operations:

- a) Pelletization or nodulisation of fly ash, and
- b) Sintering of fly ash pellets or nodules at 1 100 °C-1 200 °C.

8.3 The pelletization of fly ash may be done by feeding fly ash into a tilted rotating pan under a fine spray of water. The rotary motion of the pan causes the material to cascade and with this pellets are formed which are strong enough to withstand subsequent handling.

8.4 Normally, fly ash contains sufficient amount of unburnt carbon to provide for the fuel required for sintering. If it does not, then, extra fuel in the form of powdered coal or coke is required. Similarly, if fly ash particles do not cohere to form pellets, additives such as shale and clay are added. Additives, if any, are thoroughly mixed in fly ash before pelletization. The sintering of the pellets may be done either in vertical shaft kiln or on a moving grate sintering strand.

8.5 IS 9142 (Part 2) provides requirements for artificial lightweight aggregate for concrete namely sintered fly ash coarse aggregate. It is suitable for use in the production of structural lightweight concrete and precast lightweight concrete building units used as load bearing and non-load bearing elements. Due to higher strength to mass ratio, lower thermal conductivity, nailability, sawability and greater resistance to fire, SFALA concrete is suitable for use in the construction of high-rise buildings. Its use speeds up construction and lowers haulage and handling costs by reduction in mass of building components. The reduction of dead loads also brings about savings in costs towards foundations and steel.

9 LIME-FLY ASH CELLULAR CONCRETE

9.1 To produce lime-fly ash cellular concrete, quick lime (calcium oxide content 70 percent minimum, magnesium oxide content 3 percent maximum) fly ash (specific surface, 3 000 cm²/g; unburnt carbon content,

5 percent maximum) and gypsum (CaSO₄·2H₂O content, 80 percent minimum) are taken in certain proportions and wet mixed in a high speed mixer to form a thin homogenous slurry. A small amount of aluminium powder (fineness: residue on 7.5 µm IS sieve one percent maximum) is then added and mixed into the slurry. Hydrogen gas liberated by aluminium and lime reaction aerates the slurry which is poured into steel moulds to 2/3rd depth and left undisturbed to set. The setting takes place in 4-5 h. The stiffened material is cut into blocks of desired sizes which are subsequently autoclaved at a steam pressure of 11-12 kg/cm². After taking out from the autoclave the blocks are allowed to cool and are stacked for use.

9.2 The properties of lime-fly ash cellular concrete are similar to the cellular concrete produced using cement and ground sand. It is lightweight, has good thermal insulation and fire resistance properties and stability under conditions of varying temperature and humidity. It can be produced with dry bulk density of 700 kg/m³ or higher and the units produced are suitable for load bearing walls in buildings of 2 to 3 storeys and partition walls in multi-storeyed buildings. Its use speeds up construction, lowers haulage and handling costs and brings about savings in costs of foundations and steel by reducing dead weight.

9.3 The production of cellular concrete using lime and fly ash in place of cement and ground sand costs comparatively less, as it eliminates the use of cement which is costlier than lime and saves the cost of grinding sand.

9.4 Requirements for cinder for use as aggregates in lime concrete are given in IS 2686.

10 CEMENT/LIME/SILICATE BONDED AND CLAY-FLY ASH BUILDING BRICKS/BLOCKS/TILES

10.1 Good quality building bricks may be produced from fly ash using sodium silicate, cement or lime as binder (with or without accelerator). The mixture of fly ash, binder and coarse fillers such as bottom ash, cinder and sand in suitable proportions may be moulded into bricks under pressure. Except for sodium silicate, the other binders have to be mixed in dry state, followed by addition of water with/without accelerator. The sodium silicate bonded fly ash bricks are burnt at 1060 to 1150 °C, but lime bonded fly ash bricks are autoclaved under saturated steam while the cement-bonded fly ash bricks are cured under water at ambient temperature to obtain the desired strength and are air-dried before use.

10.2 The process of manufacturing clay-fly ash building bricks is similar to that of production of normal clay bricks except that a certain amount of fly ash is mixed in the clay before moulding bricks. The actual content

of fly ash added varies according to the plasticity of clay and may range from 30 to 70 percent by volume, as the clay changes from moderately plastic to highly plastic. Fly ash acts as a good opening material and effectively eliminates drying cracks in the bricks produced from black cotton clays. The unburnt carbon present in fly ash provides extra fuel for burning during firing. The rate of fire travel during burning of clay-fly ash bricks in the brick kiln is also enhanced. Consequently, overall fuel consumption is reduced and production per season increased. The fly ash building bricks may be used in place of common burnt clay bricks for all types of brick masonry.

10.3 Insulating and Semi-insulating Bricks

Good quality insulating and semi-insulating bricks may be produced from fly ash using china clay, saw dust and molasses or spent lye as binder. The mixture of fly ash and other constituents in suitable proportions are soaked for about a week and moulded into bricks under slight pressure. The bricks are air-dried and burnt in kilns at 1 100 °C to 1 150 °C. These bricks having desired properties in accordance with IS 2042 can be used for back face insulation of furnaces and other similar equipment. Insulating bricks can also be produced using the same procedure, after reducing the iron-oxide content of fly ash by suitable processing.

10.4 IS 12894, IS 13757 and IS 16720 provide the requirements for Pulverized fuel ash lime bricks, burn clay fly ash building bricks and pulverized fuel ash cement bricks respectively.

11 PORTLAND CEMENT CLINKER

11.1 Fly ash compares well with clay as a source of silicon dioxide and aluminium oxide. It may be used in place of clay in the raw meal for producing portland cement clinker by the semi-dry process. Small pellets or nodules (diameter 12.5 mm or less) of the raw meal consisting of an intimate mixture of the required quantity of ground limestone and fly ash may be prepared in a tilted pan pelletizer under a fine spray of water. Any other type of nodulizer may also be used for nodulizing the raw meal.

11.2 The nodules are fed into the rotary kiln and burnt at 1350 °C to produce portland cement clinker, which on cooling is ground with 4 percent gypsum by mass, to obtain portland cement.

11.3 The production of cement clinker at 135 °C, instead of about 1450 °C normally employed, brings about a substantial saving in fuel consumption. In addition, it has been found that the use of fly ash in place of clay in the raw meal enables production of cement clinker with magnesium oxide content of 6 percent without causing unsoundness in the final cement. Thereby, it also helps in the utilization of magnesium limestone of marginally

higher magnesium oxide content, which at present, is not used by the cement industry.

12 OIL WELL CEMENT

12.1 Oil well cement is used for cementing the steel casings of oil wells to the rock formation. The cement slurry is pumped down through the steel casing to points located in the annulus around the casing, in the open hole below or in permeable formation around. For satisfactory performance under conditions of high temperature and pressure, which in deep wells may be as high as 350 °C and 1 400 kg/cm² respectively or even more, it is essential that the cement slurry has ample fluid time to enable proper placement before setting and then harden fairly rapidly to give sufficient strength to support the casing and resist corrosive conditions of sulphur bearing gases or water containing dissolved salts.

12.2 Cement produced by intergrinding fly ash as admixture, Portland cement clinker, gypsum and other admixtures in suitable proportions has been found to conform to the requirements of an oil well cement. It may be commercially produced at cement works which are located within economic distance of thermal power stations. Such a fly ash based cement is reported to have been successfully used in cementing oil wells.

12.3 Requirements for oil well cement are given in IS 8229.

13 MASONRY CEMENTS

13.1 Masonry cement is mainly intended for use in place of ordinary Portland cement in masonry mortars. It imparts, to the masonry mortars, much desired properties of high workability, plasticity and water retentivity.

13.2 It has been shown that masonry cement conforming to the standard requirements can be produced by intergrinding 2 parts of fly ash, 2 parts of hydrated lime and 1 part of Portland cement clinker or 5 parts of fly ash, 3 parts of Portland cement clinker and 5 parts of granulated blast furnace slag with suitable quantity of gypsum and an air entraining admixture. The production of these masonry cements and their utilization in the building industry will ease pressure on the demand of Portland cement.

13.3 Requirements for masonry cement are given in IS 3466.

14 FLY ASH UTILIZATION IN ROAD AND AIRFIELD PAVEMENT CONSTRUCTION

14.1 Lime-Fly Ash Concrete

14.1.1 Lime-fly ash concrete possesses significant flexural rigidity and thus offers superior load dispersion

property in pavements as compared to conventional granular material, such as water bound macadam. Investigation have shown that when lime conforming to IS 712 and fly ash to IS 3812 (Part 1 and/or Part 2) is used for making lime-fly ash concrete of mix proportion 1 lime, 2 fly ash, 3 sand and 6 coarse aggregate has an equivalency factor of 1.5 in relation to water bound macadam and, therefore, permits a reduction of 33 percent in the thickness of the layer replaced. In view of better load dispersion characteristics of lime fly ash concrete such bases or sub-bases are particularly suitable in areas having heavy rain-fall, poor drainage or weak subgrade for longer life and improved serviceability of the pavement. IS 5817 describes practice for preparation and use of lime-pozzolana mixture concrete in buildings and roads.

14.1.2 Investigations have shown that the lime-fly ash concrete of mix proportion as given in 13.1.1 can be successfully used for making precast lime-fly ash concrete blocks for foot paths. These precast blocks, however, require a top bonded layer 10 mm thick of cement-sand mortar

(mix 1:3 and w/o 0.55 by mass) in view of low resistance to abrasion of lime-fly ash concrete. The suitable size of blocks is 30 cm × 30 cm × 10 cm. Instead of making precast blocks, lime-fly ash concrete can be rolled *in situ*. As in the case of precast blocks, in this case also the top mortar layer is to be laid simultaneously.

14.1.3 Lime-fly ash concrete can also be used for making building bricks and hollow blocks. IS 2541 describes the requirements for lime-fly ash concrete. IS 10359 describes the practice for manufacture and use of lime-pozzolana concrete blocks for paving. IS 10360 describes the requirements for lime-pozzolana concrete blocks.

14.2 Lean Cement-Fly Ash Concrete

Lean cement concrete tends to segregate, bleed, has low plasticity and cohesiveness when green. The addition of fly ash improves upon such shortcomings of lean concretes. In lean cement concrete, the cement content is already low, so partial replacement of cement by fly ash is not advisable. Studies have shown that the benefits of fly ash addition can be maximized in the case of lean concretes by resorting to partial replacement of fine aggregate by fly ash which permits use of larger quantities of fly ash. Such partial replacement of fine aggregate by fly ash also makes available additional quantity of binder material in the mix due to pozzolanic reaction between the lime released as a result of cement hydration and the fly ash, leading eventually to increased strength for the resultant concrete. Investigations have shown about 100-175 percent increase in compressive strength of cement-fly ash concrete in which 50 percent of fine aggregate is replaced by fly ash over plain mixes (without fly ash) of equivalent proportions.

Such concrete would be cheaper than plain concrete. Suitably designed mixes can be used as base or sub-base course in road and air-field pavement construction in place of conventional water bound macadam. It can also be used in building foundations particularly where water table is high.

14.3 Cement-Fly Ash Concrete

The laboratory, semi-field and full scale field experiments have shown that 15-20 percent cement by mass can be replaced by fly ash conforming to IS 3812 (Part 1 and/or Part 2) thereby affecting 10-15 percent saving in the initial cost of construction besides releasing cement for other works. IS 456 describes the practice for plain and reinforced concrete by using flyash.

14.4 Lime-Fly Ash Soil Stabilisation

Soil when stabilized with lime, fly ash can be used economically as sub-base both for roads and runways in place of granular materials. The Unconfined Compressive Strength (UCS) criteria shall be the design criteria for use in sub bases. When lime and fly ash are used for soil stabilization minimum requirement of UCS after 7 days curing shall be 700 kN/m² as per the requirements. The mix proportion shall be arrived at, for a particular fly ash, soil and lime by conducting UCS test in accordance with IS 5817. IS 4332 series of standards provide methods of sampling and tests for stabilized soils.

14.5 Lime-Fly Ash Bound Macadam

In conventional water bound macadam, non-plastic or low-plasticity materials like morrum with or without screenings are used as filler for the stone metal. When such water bound macadam is used in the upper layers of a road pavement, thin bituminous surfacings like surface dressing or premix (open graded) thereon, permits penetration of water into it. Fillers made of a mixture of lime, fly ash and sand/morrum/soil in suitable proportion are known to improve the situation as these have cementitious properties and do not soften in presence of water. The usual proportion for the filler mix is 1 lime: 2 fly ash : 9 sand/morrum/soil by mass. Studies have shown that load bearing capacity of such macadam will be superior to that of conventional water bound macadam. The conventional water bound macadam may be replaced by lime or cement stabilized fly ash-soil mixtures. It is expected that water bound macadam course constructed with lime-fly ash-sand as filler would have longer life and would contribute to better serviceability of the road.

The mix proportion may be arrived by carrying out Unconfined Compressive Strength (UCS) tests on compacted samples in the laboratory. Stabilized mixtures with different lime and cement contents are moulded into compacted samples and cured for 7 days.

The design criteria for use of stabilized fly ash-soil mixtures in base construction is minimum strength requirement of 1717 kN/m² after 7 days moist curing. The lime or cement stabilized fly ash-soil mixture would provide longer life and would contribute to better serviceability of road.

15 FLY ASH AS FILL MATERIAL IN EMBANKMENT CONSTRUCTION

15.1 Number of field studies has indicated the feasibility of fly-ash as an alternative material for construction of embankments. The utility of fly ash in embankment saves huge quantify of good earth which otherwise would have formed top fertile layer of earth.

15.2 However, ash is a very fine material and starts blowing with the wind when dry. As such it is important to encase it suitably with compacted earth/heavier material to avoid ash becoming airborne.

15.3 Fly ash is of silt size and a non-plastic material. It has low specific gravity or low bulk density making it most suitable for construction on soft soils. Hence, the properties to be kept in view are grain size, density, shear strength, compaction characteristics and permeability.

15.4 The moisture-density curve is flat indicating that its dry density is insensitive with moisture content. This property makes it possible to continue the construction of fly ash embankment layers during rainy season.

15.5 The fly ash has better angle of shearing resistance compared to soil and it ranges between 25-38°. Consolidations tests have indicated that fly ash is having low compressibility index in the range of 0.07 – 0.05. Hence, fly ash is of low compressible nature

and most of the settlement of fly ash embankment gets completed during construction itself.

15.6 The fly ash has to be compacted at optimum moisture which is normally in the range of 15-30 percent. Because of its low density the material is suitable for locations where clayey soils get consolidated under overburden material. The permeability of compacted fly ash is low (0.05×10^{-7} to 8×10^{-7} m/s) so in cases where the water table is very high or surface water likely to percolate down the embankment it is advisable to provide for drainage a layer of coarse material 300-450 mm thick below the fly ash.

15.7 All these geotechnical characteristics makes it suitable for embankment construction.

16 FLY ASH AS FILLER MATERIAL IN BITUMINOUS CONCRETE

Bituminous concrete paving mixtures are usually designed with a small percentage of fine material like cement or lime dust mostly passing through 75 μ m IS sieve. Fly ash compares well with conventional materials in respect of fineness. When fly ash is used as a filler due to the presence of unburnt carbon, the amount of bitumen required is a little more, but because of low cost of fly ash the resultant mix may be somewhat cheaper or at par.

17 AGRICULTURE/WASTE LAND DEVELOPMENT

Fly ash can be used for agricultural purposes specifically to optimize the water carrying capacity of soil. It can be mixed with top layer of agricultural soil up to one centimeter thick layer (that is, 100 tonne/hectare) to optimize its water carrying capacity for a better yield.

ANNEX A

(Foreword)

COMMITTEE COMPOSITION

Solid Waste Management Sectional Committee, CHD 33

<i>Organization</i>	<i>Representative(s)</i>
In personal capacity	DR ANURADHA SHUKLA (Chairman)
Alkali Manufacturers' Association of India	SHRI K. SRINIVASAN DR H. S. DAS (<i>Alternate</i>)
Avantha Centre for Industrial Research, Yamunanagar	DR NISHI KANT BHARDWAJ SHRI SANJEEV GUPTA (<i>Alternate</i>)
Cement Manufacturers Association, New Delhi	SHRI ANIL KUMAR TRIVEDI SHRI P. SREENIVASA RAJU (<i>Alternate</i>)
Central Pollution Control Board, New Delhi	SHRI J. S. KAMYOTRA
Central Road Research Institute, New Delhi	SHRI GURUVITTAL DR NEERAJ SHARMA (<i>Alternate</i>)
Confederation of Indian Industry, New Delhi	MRS SEEMA ARORA SHRI KAMAL SHARMA (<i>Alternate</i>)
Delhi Technological University, Delhi	DR RAKESH MEHROTRA DR (SHRIMATI) ANUBHA MANDAL (<i>Alternate</i>)
Development Alternative	DR K. VIJAYA LAKSHMI DR SOUMEN MAITY (<i>Alternate</i>)
Engineers India Limited, New Delhi	SHRI R. S. PRASAD SHRI VIKRAM SINGH (<i>Alternate</i>)
Federation of Indian Chambers of Commerce and Industry, New Delhi	MS ARCHANA DATTA MS SUCHISMITA MUKHOPADHYAY (<i>Alternate</i>)
Fly Ash Mission, Department of Science and Technology, Ministry of Science, GOI	DR R. K. JOSHI
In personal capacity	DR N. B. MAJUMDAR
In personal capacity	DR VIMAL KUMAR
In personal capacity	MRS SANCHITA JINDAL
In personal capacity	SHRI PRADEEP KUMAR KHANDELWAL
Indian Centre for Plastics in the Environment, Mumbai	SHRI T. K. BANDOPADHYAY SHRI GOPAL JHA (<i>Alternate</i>)
Indian Chemical Council, Mumbai	DR N. J. SINGH SHRI A. A. PANJWANI (<i>Alternate</i>)
Indian Oil Corporation Ltd, Faridabad	DR M. P. SINGH
Infrastructure Leasing and Financial Services	SHRI NEERAJ CHANDRA SHRI SANDEEP MALHOTRA (<i>Alternate</i>)
ITC Limited	SHRI SANJIB BEZBAROA
Ministry of Defence, DRDO, New Delhi	AWAITED DR S. MARY CELIN (<i>Alternate</i>)
Ministry of Environment, Forest and Climate Change	AWAITED SHRI E. THIRUNAVUKKARASU (<i>Alternate</i>)
Ministry of Urban Development, New Delhi	SHRI UDIT RATNA SHRI P. K. DURIA (<i>Alternate</i>)

<i>Organization</i>	<i>Representative(s)</i>
National Council for Cement and Building Material, New Delhi	SHRI N. K. TIWARY SHRI M. SELVARAJAN (<i>Alternate</i>)
National Solid Waste Association of India	SHRI AMIYA KUMAR SAHU CAPT MANJU MINHAS (<i>Alternate</i>)
NTPC Limited, New Delhi	DR S. K. JAIN DR SUDHIR DAHIYA (<i>Alternate</i>)
PHD Chamber of Commerce	NOMINATION AWAITED
Steel Authority of India Limited, New Delhi	DR MEENAKSHI KAKKAR SHRI SUNIL SINGAL (<i>Alternate</i>)
Steps Pvt Ltd	SHRI T. RAGHAVENDRA RAO
Sulabh International Social Service Organization	AWAITED
The Energy and Resources Institute, New Delhi	COL R. K. JOHRI (RETD) DR SUNEEL PANDEY (<i>Alternate</i>)
The Fertilizer Association of India, New Delhi	SHRI MANISH GOSWAMI SHRI G. M. PATEL (<i>Alternate</i>)
Town and Country Planning Organization, M/o Urban Development and Poverty Alleviation, New Delhi	SHRI K. K. JOADDER DR SANTHOSH VIDYADHARAN (<i>Alternate</i>)
BIS Directorate General	SHRI A. K. LAL, SCIENTIST 'E' AND HEAD (CHD) [REPRESENTING DIRECTOR GENERAL (<i>Ex-officio</i>)]

Member Secretary

SHRISHTI DIXIT
SCIENTIST 'D' (CHD), BIS

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